9412

NATIONAL BUREAU OF STANDARDS REPORT

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PERFORMANCE CHARACTERISTICS OF EXTERIOR WALLS

Progress Report for Period Ending June 30, 1966

Edited by

J. V. Ryan

to

Federal Housing Administration
U.S. Department of Housing and Urban Development
Washington, D.C.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT 421-2405

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NBS REPORT 9412

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J. V. Ryan
Building Research Division

1. INTRODUCTION

The objectives of this project are to adapt or develop test methods and techniques for the measurement of the performance characteristics of exterior walls, and to provide values obtained by such tests when applied to representative walls. This project was designed to bring under consideration all the characteristics of exterior walls and to determine which are of importance. For the latter, means of measurement are sought and values obtained. These are expected to form the basis for decisions as to the levels of performance against which to judge walls of various types.

2. PROJECT PLAN

The plan of the project called for (1) an analysis of the functions of exterior walls in order to develop a list of all characteristics and the selection of those subject to physical measurement, (2) review of existing test methods having potential applicability, (3) testing of representative samples by these methods, (4) development of additional test methods and apparatus as needed, (5) measurement of the performance characteristics of samples of representative wall systems by all the various methods, and (6) where possible, suggest limiting values for each of the significant wall performance characteristics subject to physical measurement.

3. ACTIVITIES

The item number (1) under Project Plan was completed in an earlier period, except as review may be required in the light of progress under the other items. Work has continued under items (2), (3), and (4). However, the principal effort over the past six months has been under item 5. This work is being carried out in all but one of the Sections of the Building Research Division.

As a result of conferences among the Division staff engaged in the project, and with staff of the Federal Housing Agency, a set of six wall constructions were agreed upon for submission to tests, per item (5) of the Project Plan. Since the original selection of basic types, some modifications have become necessary among the prefabricated walls due to changes in what has been available on the market. A seventh wall was added at the request of the sponsor. The present types are:

1. <u>Framing</u>: 2x4's, common pine or fir, 16 in. o.c. with firestops near midheight.

Exterior: 1/2 in. insulating fiber sheathing nailed to studs; 1 in. air space; single wythe 4 in. common face brick, with ties nailed to framing (through sheathing).

Interior: single layer of 1/2 in. aluminum foil backed gypsum wallboard, nailed to studs with joints vertical, joints taped and cemented, nailheads cemented; two coats of self-sealing latex base paint.

2. Framing: same as 1 above.

   Exterior: 1/2 in. insulating fiber sheathing nailed to studs; 1x6 air-dried select wood drop siding nailed through sheathing to studs; painted per MPS.

   Interior: same as 1 above.

3. Exterior: 4 in. common face brick backed with 4 in. cinder aggregate concrete block (3 oval hollow cores); each set in mortar.

   Interior: 1x2 wood furring, nailed vertically, at 16 in. o.c., with horizontal strips at top, bottom, and midheight; drywall and paint as 1 above.

4. Sandwich wall: (prefabricated) consisting of aluminum skins and paper honeycomb core. Surface coatings (paint) as per normal production of the manufacturer.

5. Sandwich wall: same as 4 except plywood skin on both faces.

6. Prefabricated: 18 ga galvanized steel Z-studs 24 in. o.c.; 18 ga top and bottom channels; 2 in. of glass fiber insulation; interior facing 1/2 in. foil-backed gypsum wallboard cemented on; exterior facing 3/8 in. exterior grade plywood siding held by barbs integral to Z-studs.

7. Framing: 2x4's, common pine or fir, about 16 in. o.c., with let in 1x4 diagonal brace.

   Exterior: horizontal aluminum siding applied directly to the studs, per FHA UM-27.

   Interior: 1/2 in. gypsum wallboard applied with adhesive and reduced nailing per manufacturers specifications.

For each of the above, enough material, or samples of prefabricated walls will be obtained in a single order to provide specimens for all tests to be carried out.

3.1 Structural and Water Permeability - T. W. Reichard

3.1.1 Racking test

Four different wall constructions have been tested using the diagonal racking equipment.

Six specimens of type 2 were tested; two each at three different edge loads. Three specimens of type 7 were tested: one at each of the three different edge loads. The results of these racking tests are given in table 1. It can be seen that if the edge-loading had any effect on the stiffness, or strength, of these panels it was obscured by the inhomogeneity of the specimens. It should be pointed out that the type 7 specimens were tested with the load applied parallel to the let-in brace; and that the strength of the brace appeared to be the controlling factor in the strength of the wall.

Table 1. Racking Test Results

Wall type	Edge Load	Horizontal Racking Load 1/ Maximum	Horizontal Racking Load 1/ at 0.2-in. Horizontal movement in 8-ft. Length
	lb/ft.	lb/ft.	lb/ft.
2 2/	0	1200	710
2 2/	630	1190	850
2 2/	1250	1280	810
7	0	1010	620
7	630	710	390
7	1250	890	640

1/ Horizontal Racking Load = 0.707 Diagonal Racking Load

2/ Average of two specimens.

The results from the tests on wall types 4 and 6 have cast some doubt on the suitability of any existing standard racking test. The controlling factor in the strength, and rigidity, of wall systems constructed from individual panels is in the strength of the connections and to a certain extent the restraint provided by the floor and roof.

For instance the equivalent horizontal racking strength of a single 4 ft x 8ft type 4 panel was found to be approximately 425 lb/ft. Using 2 - 4 ft x 8ft panels connected as per manufacturer's recommendations the strength was only 180 lb/ft for the 8ft x 8ft assembly. There is no doubt that the connections specified are inadequate, however there is also no doubt that, with the restraint provided by the floor and roof, the wall system would come closer to utilizing the full racking strength of the individual panels.

3.1.2 Wind Load and Water Permeability Test

Wall types 4 and 7 were tested for both wind load and rain penetration. Both types were very permeable to air; in fact so permeable that the air supply was insufficient to provide the 50 psf wind load without special sealing of the joints. Both walls were fairly elastic in their reaction to the simulated wind load, but were not as stiff as the more-conventional type walls (Type 2).

The through-wall water leakage of both walls, with 10 psf wind pressure, was considerable. Wall type 4 which was poorly sealed at all edges except the floor joint started to leak immediately at a rate of about 160 lb/hr. Wall type 7 started to leak in about 20 min. at about 2 lb/hr.

3.1.3 Compressive and Transverse Load Tests

The testing of the walls, using the ASTM E-72 procedures is continuing. The transverse-load test results will be correlated with the results from the tests in the wind and rain test chamber. This will be done in order to check the effect of the edge restraint (in the chamber) on deflection.

The compressive strength of types 4 and 6 was 3100 lb/ft., type 7 was 5600 lb/ft. while type 2 was 10,200 lb/ft. Wall type 7, which failed due to buckling, exhibited no sign of any type of permanent distress after removal of load. All other walls tested exhibited some form of structural damage after testing.

3.2 Smoke Production - D. Gross

A detailed report on the smoke measurement apparatus was appended to the report for the period ending December 31, 1965. The information contained therein was prepared for presentation as part of a symposium on smoke held during the Annual Meetings of the American Society for Testing and Materials. The manuscript had been given appropriate review and approval by the National Bureau of Standards and the Federal Housing Administration prior to being offered for presentation at the symposium. It is expected that ASTM will publish the symposium papers, probably as one of their Special Technical Publications.

Specimens from the typical walls (in Section 3) will be tested as they are obtained. In some cases extra materials are to be ordered: in others samples will be cut from large panels after the latter have been subjected to racking or other tests. The specimens will be subjected to three fire test methods: 1) the smoke production test, the details of which were reported with the last report; 2) the surface flammability test of ASTM E162; and 3) a flame penetration test using the apparatus of Federal Specification SSA-118b.

3.3 Air and Water Vapor Transfer - T. K. Faison

Because of mechanical failures in the refrigeration system, progress on the testing of the six typical wall specimens for performance characteristics has been minimal. The contractor having the responsibility to furnish

the refrigeration system according to specifications, has had great difficulty in getting the system operational and maintaining the required control of conditions. Much of the delay has been caused by the mechanical failure of a number of compressors and the break-down of the refrigerant pump.

Once the refrigeration system seems to be functional, a short period of operation will be required to check out the entire system to determine if all phases of control necessary for the test (temperature, humidity, and pressure control, air flow rate measurement, physical deflection, etc.) can be achieved. The control features not directly related to the refrigeration system have been tested individually and seem to be adequate for their specific function. The chambers, both warm and cold, have performed very satisfactorily during the periods when the cold side temperature was at 0 F and the warm side temperature was at 70 F. The trial wall of 1/2-in. plywood has provided the barrier between the two spaces and control of temperature and humidity on the warm side has posed no problem.

Upon satisfactory control of the cold side temperature, the activity on the program will be increased to achieve maximum results prior to the move to Gaithersburg.

3.4 Weathering, Discoloration, Abrasion, etc. - W. C. Wolfe

Additional tests were performed on siding materials by the same methods described in previous reports and by different methods. Steel siding is being introduced for uses similar to aluminum siding and it was considered important to compare both products. The effects, on performance, of the advantages and disadvantages of each product need to be investigated. Steel is harder and stiffer than aluminum and would be expected to have greater dent resistance; there should be less damage during installation from bending or distrotion in handling; and there should be less "oil canning" or waviness after installation. However, steel is harder to cut than aluminum. Aluminum can be cut with ordinary tinsnips or scored with a knife, while steel requires special airplane shears. Also steel will rust if the coating is scratched through.

Weatherometer Tests

In order to determine whether steel siding presents a corrosion problem, as compared to aluminum siding, weatherometer tests were run on specimens cut from both types. The aluminum siding came finished with a thin, smooth coat of acrylic enamel. The steel siding came in two finishes, one a thin, smooth coating and the other a thicker, textured coating called "Plasticol". Exposure to a xenon arc in a dry atmosphere for 1172 hours had no effect on any of the three specimens tested, one of each type of siding. Another set of three specimens was exposed for 1100 hours in a carbon arc weatherometer with a cycle of 3 minutes tap water spray and 17 minutes dry. The aluminum and the smooth finish steel specimen were unaffected but the Plasticol coated steel specimen was stained yellow, indicating rust.

3.5 Impact Resistance - W. C. Wolfe

While no tests have been performed with a simulated hail gun, a desk study of the subject was continued. According to early investigators, a 2 1/2-in. diameter hailstone has a terminal velocity of about 120 ft/sec, while a 3-in. diameter hailstone has a terminal velocity of about 130 ft/sec. J. A. P. Laurie (1) reported the design and construction of an air gun which would fire an ice sphere 2 1/2 in. in diameter, weighing 110-150 grams, up to 150 ft/sec, with an air pressure of 180 psi. Complete drawings have been obtained which would enable construction of this air gun. A gravity system would require too high a drop to be practicable. For low velocities of this order, air resistance can be neglected. From the classic formulas, it can be seen readily that a 224 foot drop is required for a terminal velocity of 120 ft/sec.

The method of preparing the ice spheres or artificial hailstones is important. Laurie (1) drilled cores from a block of ice and molded them into a roughly spherical shape. Ice spheres made by pouring water into a mold and then freezing are reported not to give the same results in impact tests. Natural hailstones are formed from the inside out in layers, an onion type structure. This might be simulated by freezing spheres in layers by successive dipping in ice water and freezing.

Private communication with Mr. Boardman, who was acquainted with Laurie and his work, indicated that Laurie and others found that the steel ball drop test did not simulate hail damage. Some tests were performed with a pendulum and impact tup at a drop height of 12 in. The tup was chisel shaped, the chisel being at a 10-degree angle. This did not break ceramic materials, as asbestos cement shingle, as readily as a ball or rounded plunger, which gives a point impact, but dents soft material, as aluminum or wood, more readily than a round tup or ball.

We considered the possibility of constructing our own pendulum impact machine. The tup would be a 1-3/4-in. diameter steel ball and the pendulum would be an aluminum bar 60 in. long. The drop height could be varied up to 120 in.

A high speed impact test machine was designed and constructed by United Engineers, Inc. of Boston, Mass. and Fabric Research Laboratories, Inc. (2) The machine was designed to test parachute materials, such as nylon webbing. It employs a gas gun with 2 1/2-in. bore, which fires missiles up to 10 lbs with velocities from 200 to 750 ft/sec.

There is also the possibility of transferring momentum from a projectile to an ice sphere. The ice, to be molded in a refrigerator, would be 2 1/2 to 3 in. in diameter and held in place on the siding with some type of special holder or clamp. A projectile could be fired at the ice sphere from an existing air gun used for textile testing at the Bureau. This gun fires a projectile 5/8-in. in diameter, weighing 50 grams. In order to transfer momentum without rebound and avoid blast, it would be necessary to place the specimen at least 12 in. from the muzzle.

Another possibility is a sling-shot type machine (3), for which complete drawings have been obtained. The machine uses heavy rubber bands about 1/2 in. in cross section and 1 ft in diameter.

Probably the best and certainly the most convenient possibility is the commercial Avalauncher, Mark 14, manufactured by Diamond King, Inc., 220 Standard Street, El Segundo, California and purchased by Mr. Sidney Greenfeld of the Asphalt Roofing Industry Bureau (ARIB). Mr. Greenfeld is located physically at the Bureau and the equipment will be available. It consists of a compressed air or gas operated gun, readily portable, with a barrel 3 1/4 in. ID and 46 in. long, producing muzzle velocity of 300 ft/sec with normal working pressure. Ice spheres would be made by Mr. Greenfeld at the Bureau, using a special mold.

A commercial machine, the Gardner Variable Impact Tester, was purchased from Gardner Laboratory, Inc. of Bethesda, Maryland. This machine consists of a cast aluminum base plate, a 2 lb steel rod impact weight, a hardened steel round-nosed punch, a removable punch die and punch holder, and a slotted, plated brass tube having graduation marks in which the selected impact rod is lifted and dropped, and a bracket to hold the tube in a vertical position. A pivot arm with hand knob aligns the punch and die and allows removal of the punch so that other punch shapes and sizes can be inserted if desired. The instrument is furnished with a 5/8-in. punch. Direct or reverse impact resistance is determined by subjecting either side of a panel to an impact of 2 in.-lb up to 80 in.-lb, in interval steps of 2 in.-lb. The range of the device may be doubled by substituting a 4-lb impact weight for the 2-lb weight. The panel is place over a 5/8-in. hole in the base plate. The steel rod is raised by lifting the pin, which extends from the rod through the slot in the tube. The rod is raised until the pin coincides with the desired graduation mark on the slotted tube, and then dropped. The test panel is then examined for flaking, cracking or deformation. Another method of operation is to place a steel ball in the tube so as to rest upon the test panel. The rod is then raised and dropped on the ball and the test panel examined as before.

For one series of tests (Tables 1 and 2) a plywood frame was built similar to but smaller than the one specified in ASTM 1037-64, "Standard Methods of Evaluating the Properties of Wood-Base Fiber and Particle Panel Materials". Two pieces of plywood frame were made, each 8- by 8- in. by 1/2 in. thick, with a square hole in the center, 3- by 3- in. A third piece of plywood was cut 8- by 8- in. by 1/2 in. thick. Each of the three pieces had corresponding 1/4-in. diameter holes to enable specimens to be clamped between two pieces. For "unsupported" impact tests, the specimens were clamped between the two plywood pieces with the square holes. For "supported" impact tests, specimens were placed on the solid piece of plywood (without hole) and one of the pieces of plywood with a square hole placed on top, then the two pieces clamped together with the specimen in between. Test specimens were cut 4 in. square and positioned so that the border around the square hole was as even as possible.

In another series of tests, 4-in. square specimens of materials were tested using the Gardner Variable Impact Tester already described. The 2-lb plunger was used and force was expressed in in.-lb, the value being twice the drop height in inches.

In a third series of tests (Tables 4 and 5), specimens were mounted in the manner actually used in houses, on a frame, 18- by 27- in., and tests performed as on page 12, NBS Report 9056, the progress report for this project for the period ending December 31, 1965.

Table 1. Drop-Impact Tests, at 90-degree angle, on 4- by 4- in. pieces of house siding, fully supported on plywood. Visible damage from 3-ft. drop (28 in-lb) of 1 3/4-in. steel ball, weighing 0.79 lb.

Siding Material	Visible Damage
Aluminum (Brands A, B, C), 22 mils thick	Deep dent in each specimen
Cement asbestos shingle (Brands A and B); 3/16 in. thick	Slight dent in each specimen
Cement asbestos board containing wood fibers, factory primed and factory painted; 3/8 in thick	Dent in each specimen
Hardboard coated with polyester; 1/2 in. thick	No effect
Plywood coated with Tedlar; 1/2 in. thick	Dent
Steel; 19 mils thick	Deep dent
Wood - Douglas fir; 3/4 in. thick	Deep dent

Table 2. Drop-Impact Tests, at 90 degree angle, on 4- by 4- in. pieces of house siding using a 1 3/4 in. diameter steel ball, weighing 0.79 lb.

Siding Material	Ht. of Drop, ft.	Impact Force, in.-lb	Visible Damage	Depth of Dent, mils
Aluminum, 22 mils thick				
Brand A	1/2	4.7	Dent; some distortion	49
	1	9.5	Deeper dent; more distortion	73
	3	28	Deep dent; deformation	
Brand B	1/2	4.7	Dent; deformation	50
	3	28	Deep dent; deformation	
Brand C	1/2	4.7	Dent; slight deformation	32
	3	28	Deep dent; deformation	
Cement asbestos, 3/16 in. thick				
Brand A	1	9.5	No effect	
	2	19	Radiating cracks on underside	
	3	28	Radiating cracks all the way through	
Brand B	1	9.5	No effect	
	2	19	Crack underneath	
	3	28	Radiating cracks all the way through	
Cement asbestos, Containing Wood Fibers, 3/8 in. thick				
Factory primed specimen	1	9.5	Slight dent	3
	2	19	Slight dent	10
	3	28	Deep dent; break in coating; slight cracking underneath	25
Factory painted specimen	1/2	4.7	Slight dent	6
	1	9.5	Dent	7
	3	28	Deeper dent	26
Hardboard Coated with Polyester, 1/2 in. thick	3	28	No effect	
	6	57	Dent; circular mar; cracking on underside	9
	10	95	Dent; more pronounced circular mar; break in material on underside	10
Plywood coated with Tedlar, 1/2 in. thick	1/2	4.7	Very slight dent	2
	3	28	Dent	12

Table 2 (con't)

Siding Material	Ht. of Drop, ft.	Impact Force, in.-lb	Visible Damage	Depth of Dent, mils
Steel, 19 mils thick	1/2	4.7	Dent; no deformation	10
	1	9.5	Dent; no deformation	35
Wood - Douglas fir, 3/4 in. thick	1/2		Mar	13
	1	9.5	Dent	

Table 3. Drop-Impact Tests, at 90 degree angle, on pieces of house siding using a Gardner Variable Impact Tester.

Siding Material	Impact Force in.-lb	Visible Damage	Depth of Dent mils
Aluminum, 22 mils thick			
Brand A	2	Dent	30
	4	Dent	50
	6	Dent	67
	12	Dent	89
	24	Dent	130
	36	Dent	147
Brand B	2	Dent	35
	4	Dent	50
	6	Dent	74
	12	Dent	96
	24	Dent	125
	36	Dent	147
Brand C	2	Dent	23
	4	Dent	44
	6	Dent	52
	12	Dent	84
	24	Dent	113
	36	Dent	134
Cement asbestos, 3/16 in. thick			
Brand A	4	Slight mar	
	6	Dent; slight bulge in back of material	
	12	Dent; bulge and crack in back of material	
	24	Deeper dent; sheet nearly punctured	
	36	Sheet punctured	
Brand B	6	Practically no effect	
	12	Dent; bulge and crack in back of material	
	24	Deeper dent; material nearly punctured	
	36	Material crushed all the way through	
Cement asbestos containing wood fibers, 3/8 in. thick			
Factory primed	4	Dent	4
	6	Dent	11
	12	Dent	26
	24	Dent	43
	36	Dent	78

Table 3 (con't)

Siding Material	Impact Force in.-lb	Visible Damage	Depth of Dent mils
Cement asbestos containing wood fibers, 3/8 in. thick			
Factory painted	4	Dent	7
	6	Dent	14
	12	Dent	20
	24	Dent	40
	36	Dent	63
Hardboard coated with Polyester, 1/2 in. thick	6	Dent	2
	12	Dent	3
	24	Dent	7
	36	Dent	8
Plywood coated with Tedlar, 1/2 in. thick	4	Dent	3
	6	Dent	5
	12	Dent	7
	24	Dent	17
	36	Dent	31
Steel, 19 mils thick	4	Dent	35
	6	Dent	43
	12	Dent	60
	24	Dent	82
	36	Dent	95
Vinyl, 1/16 in. thick	12	None	
	24	Dent	43
	36	Dent	91
Wood - Douglas fir, 3/4 in. thick	4	Dent	12
	6	Dent	17
	12	Dent	17
	24	Dent	33
	36	Dent	47

Table 4. Drop-Impact Tests, at 90 degree angle, on sections of house siding mounted on an 18- by 27- in. wooden frame, using a 1 3/4-in. diameter steel ball. Weight of ball 0.79 lb.

Siding Material	Height of drop, ft	Visible Damage Resulting from Drop- Impact[1] on Flat Surface	on Butt or Edge
Aluminum siding backed with plastic foam (aluminum, 21 mils thick; backing 3/8 in. thick)	1	Dent about 3/8 in. diam.	Slight bulge, 3/8 in. diam.
	3	Noticeable dent, 3/4 in.	Dent, marked deformation, 5/8 in.
	6	Dent, 5/8 in. diam.	Dent, marked deform., 7/8 in.
	10	Large, deep dent, 1 in.	Marked dent, deform., 1 1/8 in.
Aluminum-corrugated paper sandwich[2]	1	Dent approx. 40 mils deep and 3/4 in. diameter	
	3	Dent approx. 100 mils deep and 1 in. diameter	
	6	Dent approx. 160 mils deep and 1 1/4 in. diam.	
	10	Dent approx. 210 mils deep; aluminum sheet bent and deformed; damaged area about 2- by 2- in.	
Steel, smooth coating, 22 mils thick	1	Very slight dent, 3/16 in.	Very slight dent, 3/16 in.
	3	Shallow dent, 1/4 in.	Shallow dent, crease; very slight bulge; damaged area 1/2 in. diameter
	6	Dent, 3/8 in. diameter	Dent, deform., 3/4 in.
	10	Dent, 1/2 in. diameter	Dent, deformation, bulge; damaged area 7/8 in. diameter
Steel, heavy textured coating, 22 mils thick	1	No damage	Very slight dent
	3	Dent, 1/4 in. diameter	Dent; deform.; 1/2 in.

Table 4 (con't)

Siding Material	Height of drop, ft.	Visible Damage Resulting from Drop-Impact[1] on Flat Surface	on Butt or Edge
Steel, heavy textured coating, 22 mils thick	6	Dent, 3/8 in. diameter	Dent; deform.; 3/4 in.
	10	Dent, 9/16 in. diameter	Dent; deformation; pronounced bulge; 13/16 in. damaged area

NOTES:

1. Size of dents or damaged areas in inches maximum diameter.

2. This product consisted of two sheets of painted aluminum with three in. of corrugated paper inside. The specimens were tested by placing on the floor and were not mounted on a frame as were the other specimens.

Table 5. Drop-Impact Tests, at 45 degree angle, on sections of house siding mounted on an 18- by 37- in. wooden frame, using a 1 3/4-in. diameter steel ball. Weight of ball 0.79 lb.

Siding Material	Height of drop, ft	Visible Damage Resulting from Drop-Impact on Flat Surface	on Butt or Edge
Aluminum siding backed with plastic foam (aluminum, 21 mils thick; backing 3/8 in. thick)	1	Slight dent about 3/8 in.	Crease; damaged area 3/8 in.
	3	Dent about 1/2 in. diameter	Dent and deformation; damaged area about 1/2 in. diameter
	6	Dent and scuffing; damaged area 1/2 in. wide and 7/8 in. long in direction of impact	Dent; deformation; scuffing; damaged area 7/8 in. wide
	10	Large, deep dent, 1 in. wide	Marked dent; deformation; damaged area 1 1/8 in.
Steel-smooth coating, 22 mils thick	1	No test run	No damage
	3	No test run	Dent; crease; scuffing; damaged area 3/8 in. wide
	6	Dent; scuffing; damaged area 5/16 in. wide; 1/2 in. long	Dent; crease; scuffing; small piece of finish removed to bare metal; damaged area 7/8 in. wide.
Steel, heavy textured coating, 22 mils thick	1	No damage	Very slight dent
	3	Shallow dent, 3/8 in.	Dent; crease; 1/2 in. wide
	6	Dent; scuffing; damaged area 5/16 in. wide by 1/2 in. long	Dent; deformation; 7/8 in. wide

Tests on specimens supported by plywood (Table 1) did not show up weaknesses in the materials as observed in practice or in tests on simulated house sections (Tables 4 and 5). Aluminum and steel gave nearly the same results, whereas Tables 4 and 5 show that aluminum is bent and deformed on impact more readily than steel, even though both might show about the same size dents with a given impact.

Tests on 4- by 4- in. specimens clamped over a 3-in. square opening were more realistic. Aluminum dented much more than steel and showed deformation. Cement asbestos cracked on impact. Hard board cracked on severe impact, which might indicate behavior of lapped boards on unsupported areas.

The Gardner Variable Impact Tester failed to show differences between aluminum and steel.

The tests showed that hardboard is definitely more impact resistant than other materials tested. Aluminum, cement asbestos board containing wood fibers, plywood, steel, and wood are dented on impact and aluminum is deformed, especially if struck on the butt or edge. However, the serviceability of the above materials is not affected. Cement asbestos shingle is cracked by moderate impact, which leaves an opening for entry of moisture and affects serviceability. Materials might be classified as:

1. Impact resistant: Not affected by moderate impact; severe impact damages appearance and serviceability. (For example, hardboard)

2. Marred by impact: This indicates that the appearance of the material is affected by moderate impact, but not the serviceability. (Moderate impact dents aluminum, cement asbestos board containing wood fibers, plywood, wood, and steel. Severe impact might puncture aluminum, will crack cement asbestos board containing wood fibers, and splinter plywood and wood.)

3. Non-resistant to impact: Serviceability is destroyed by moderate impact. (Cement asbestos shingle).

3.6 Dynamic Thermal Performance of Exterior Walls - B. A. Peavy

NBS Report No. 9410 "Dynamic Thermal Performance of Exterior Walls" has been prepared and, after reproduction, copies will be furnished as an addendum to this progress report.

The report concerns the development of a laboratory test method whereby the characteristics of a composite non-homogeneous exterior wall construction, in regard to thermal behavior under conditions of periodically-varying exterior insolation and air temperatures, can be effectively measured. A test method for such measurements is not now available, although the importance of such information is increased by current trends to light-weight wall construction.

A schematic model for a test apparatus and method was devised, and mathematically analysed to provide a rigorous basis for two thermal parameters - an "effective thermal conductivity" and an "effective diffusivity" for a composite nonhomogeneous wall to characterize it as a homogeneous wall of equal overall thickness and thermal performance under sinusoidally-varying exterior conditions. To do so, however, it is necessary to fix upon a definite period for the sinewave; a 24-hr period is satisfactory and comports reasonably with actual exterior variations. These matters are presented in the report. It will be of interest that in mathematically examining two two-layer composite walls, identical except that in one the outdoor face is the indoor face of the other, large differences in effective conductivity and effective diffusivity were found, for a 24-hr period.

A chief conclusion of the report is that it is experimentally feasible, and it is believed practically feasible, to build and operate an apparatus for the determination of the effective thermal parameters of composite walls. The parameters determined would serve to characterize different walls and to indicate significant differences between them in regard to periodic heat flow. By testing various walls, of types that are conventional or considered generally satisfactory in service as regards periodic thermal performance. the ranges of values of the parameters that represent usual or satisfactory performance can be developed, against which to compare values for new or different kinds of wall. Thus, the construction and operation of the apparatus would enable a step forward in assessing the qualities of wall constructions from the point of view of realistic thermal performance.

There is a further possibility of potential importance. The parameters obtained refer to those of a homogeneous wall of thickness and thermal response equal to that of the tested composite wall. It is feasible, therefore, with these parameters to calculate mathematically the thermal response at any time of the indoor side of the wall to periodic outdoor variations of conditions. To do so, as a practical matter, would require use of a digital computer program, which could readily be furnished, and used at low cost. However, an essential input for this computation is a statement of the exterior variable climatic condition appropriate for a given case as a design condition. At present, such design conditions, for periodic exterior exposures, are not available, and undoubtedly their development would be a major undertaking. Such information is not needed for the more limited task of intercomparing one wall with another, but is necessary to enable designers to calculate heating or cooling loads realistically under periodically-varying outdoor climatic conditions.

Since a test method is feasible, and is essential for developing information needed for characterizing composite wall constructions in regard to periodic heat flow performance, it is recommended that a wall-testing apparatus be built for the purpose. A start in the direction of developing testing facilities and information for taking account of the variable periodic heat transfer performance of walls is of growing importance at this time, in view of the increasing use of air conditioning in buildings and dwellings, and of trends toward the use of light-weight and panel constructions.

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